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Publication date:
2015

Document Version
Peer reviewed version

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Citation (APA):

Kother, L. K. (Author), D. Hammer, M. (Author), C. Finlay, C. (Author), & Olsen, N. (Author). (2015). An Equivalent Source Method for Modelling the Lithospheric Magnetic Field Using Satellite and Airborne Magnetic Data. Sound/Visual production (digital)

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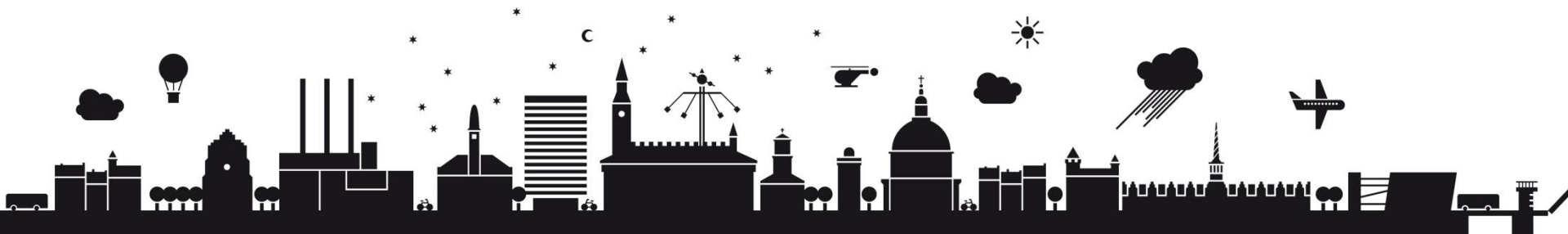
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An Equivalent Source Method for Modelling the Lithospheric Magnetic Field Using Satellite and Airborne Magnetic Data

Livia Kother¹, Magnus D. Hammer², Christopher C. Finlay¹, Nils Olsen¹

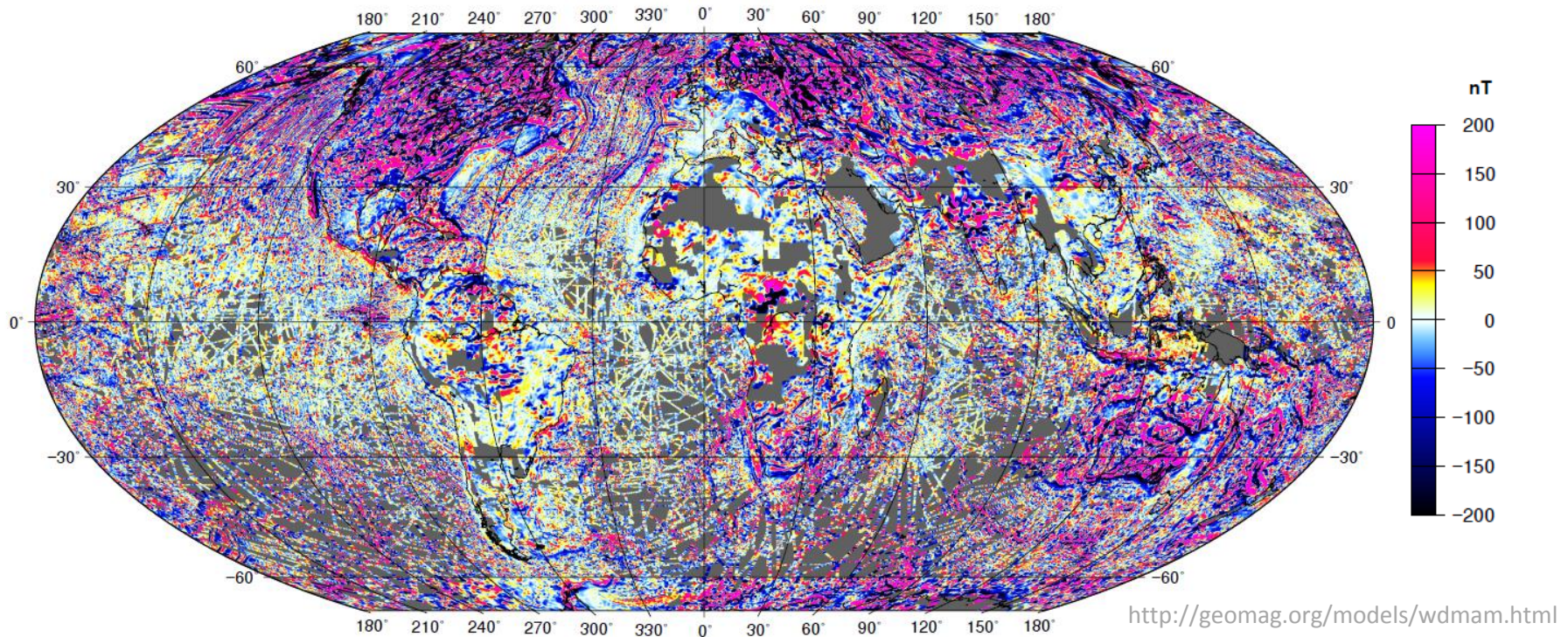
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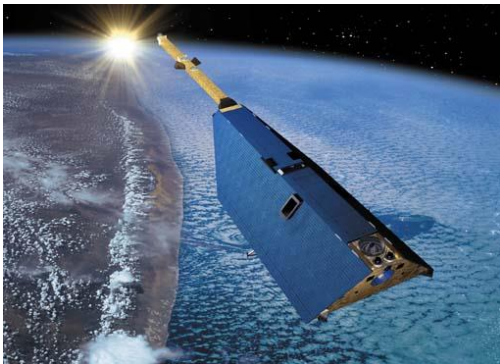
Importance of lithospheric magnetic field models

- Lithospheric structure and composition
- Resource exploration
- Directional drilling
- **High resolution models require combination of both satellite and airborne/marine measurements**



Applied Geomagnetic Data

Satellite data



<http://www.astrium.eads.net/en/programme/champ-cta.html>

- CHAMP
- Solar quiet period
- Altitude ~ 300 km
- Global model
- Resolution ~ 400 km

Airborne data

www.ngu.no

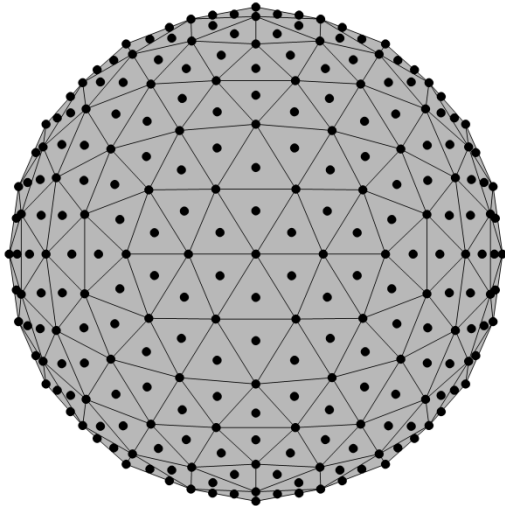


- Local surveys
- Norwegian coast
- Local model
- Resolution ~ 5 km

Data combination

- Global field structure defined by satellite data
- Local high resolution data provided by airborne data
- Better description of short wavelength structures

Applied Modelling Method - Equivalent Sources



- Icosahedron grid of magnetic point sources q

$$\hat{\Phi}(\mathbf{r}_i) = \sum_{k=1}^K q_k \frac{r_k^2}{r_{ik}}$$

$$\mathbf{B}_L(\mathbf{r}_i) = -\nabla \hat{\Phi}(\mathbf{r}_i)$$

- Model values are transferable to spherical harmonic representation

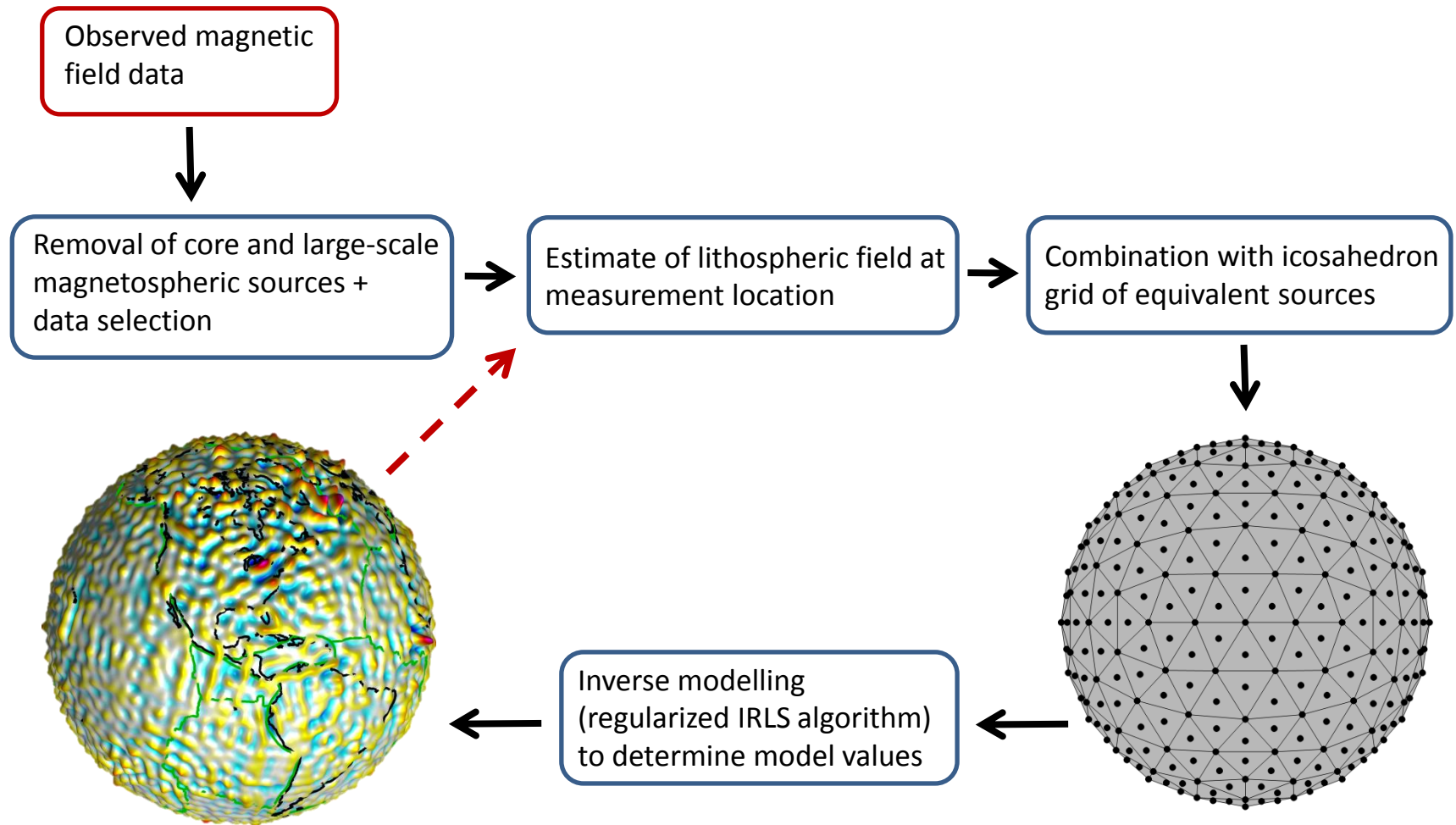
$$g_n^m = \sum_{k=1}^K \left(\frac{r_k}{a} \right)^{n+2} q_k P_n^m(\cos \theta_k) \cos(m\phi_k)$$

$$h_n^m = \sum_{k=1}^K \left(\frac{r_k}{a} \right)^{n+2} q_k P_n^m(\cos \theta_k) \sin(m\phi_k).$$

- Divergence-free constraint

$$\sum_{k=1}^K q_k = 0$$

Inverse Modelling Scheme



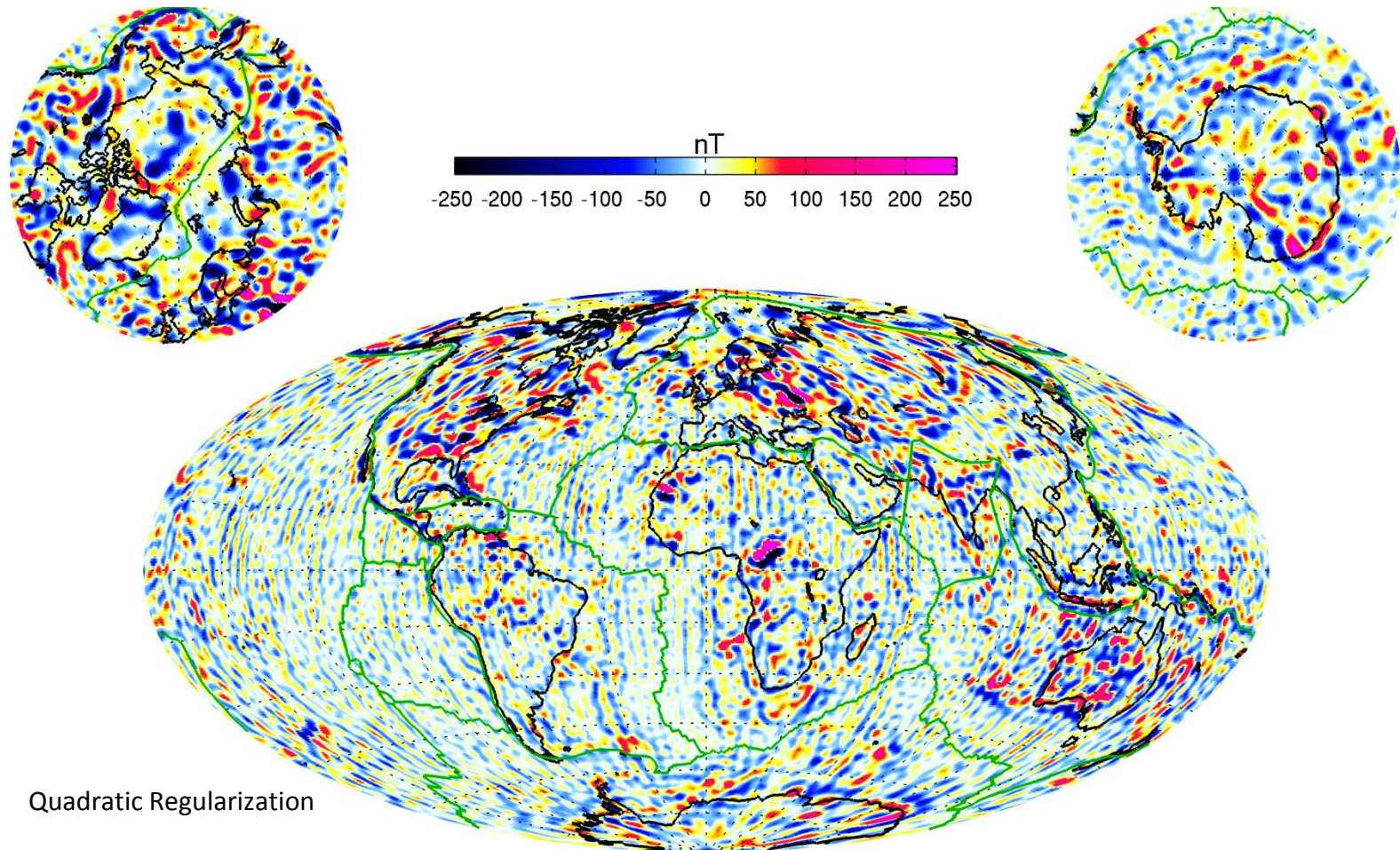
Model Estimation

- Uniqueness problem \rightarrow regularization

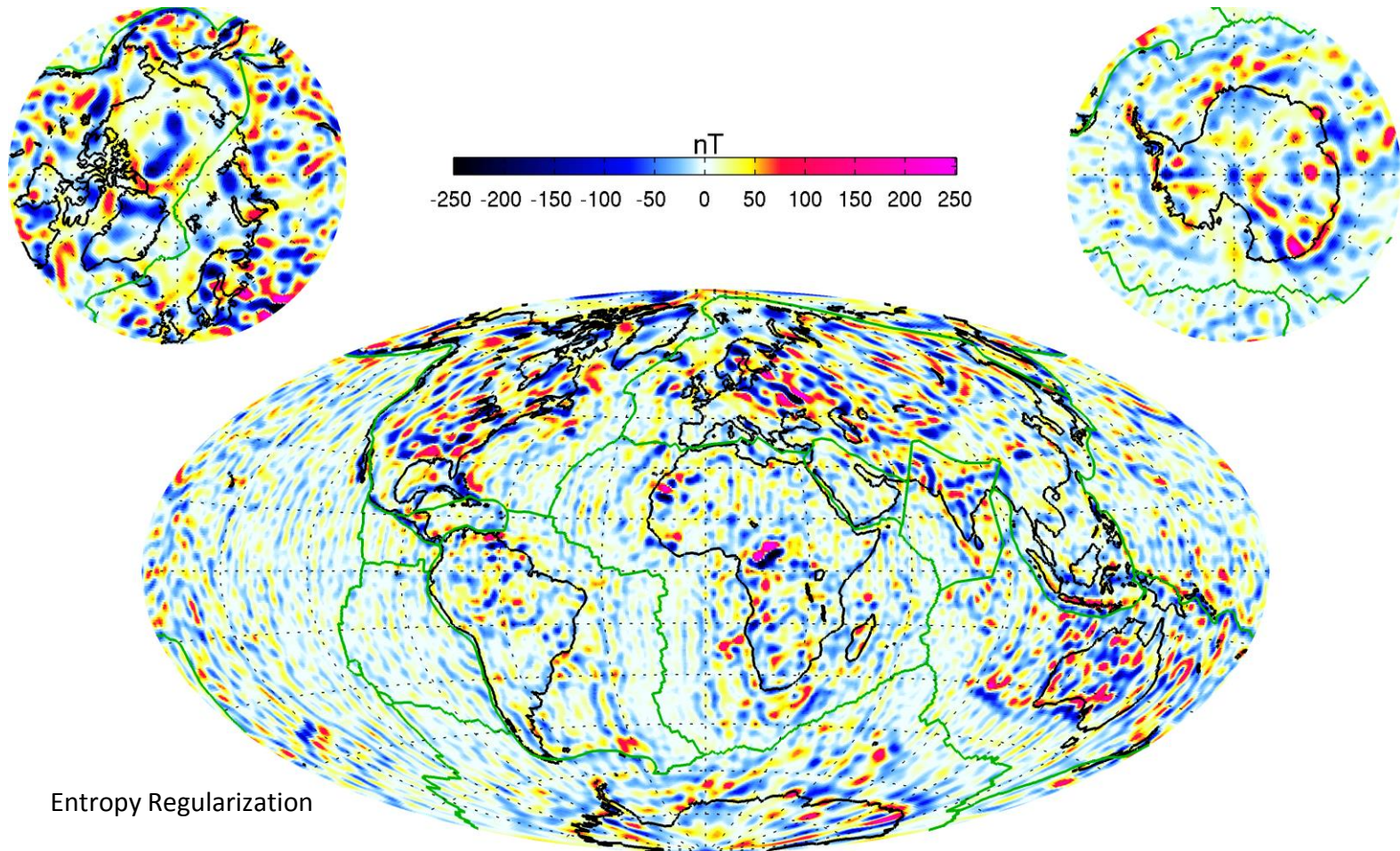
$$\Theta(\mathbf{q}) = (\mathbf{d} - \underline{\underline{\mathbf{G}}}\mathbf{q})^T \mathbf{W} (\mathbf{d} - \underline{\underline{\mathbf{G}}}\mathbf{q}) + \lambda \mathbf{R}(\mathbf{q})$$

$$\mathbf{W} = \underline{\underline{\mathbf{C}}}^{-1/2} \underline{\underline{\mathbf{H}\mathbf{C}}}^{-1/2}$$

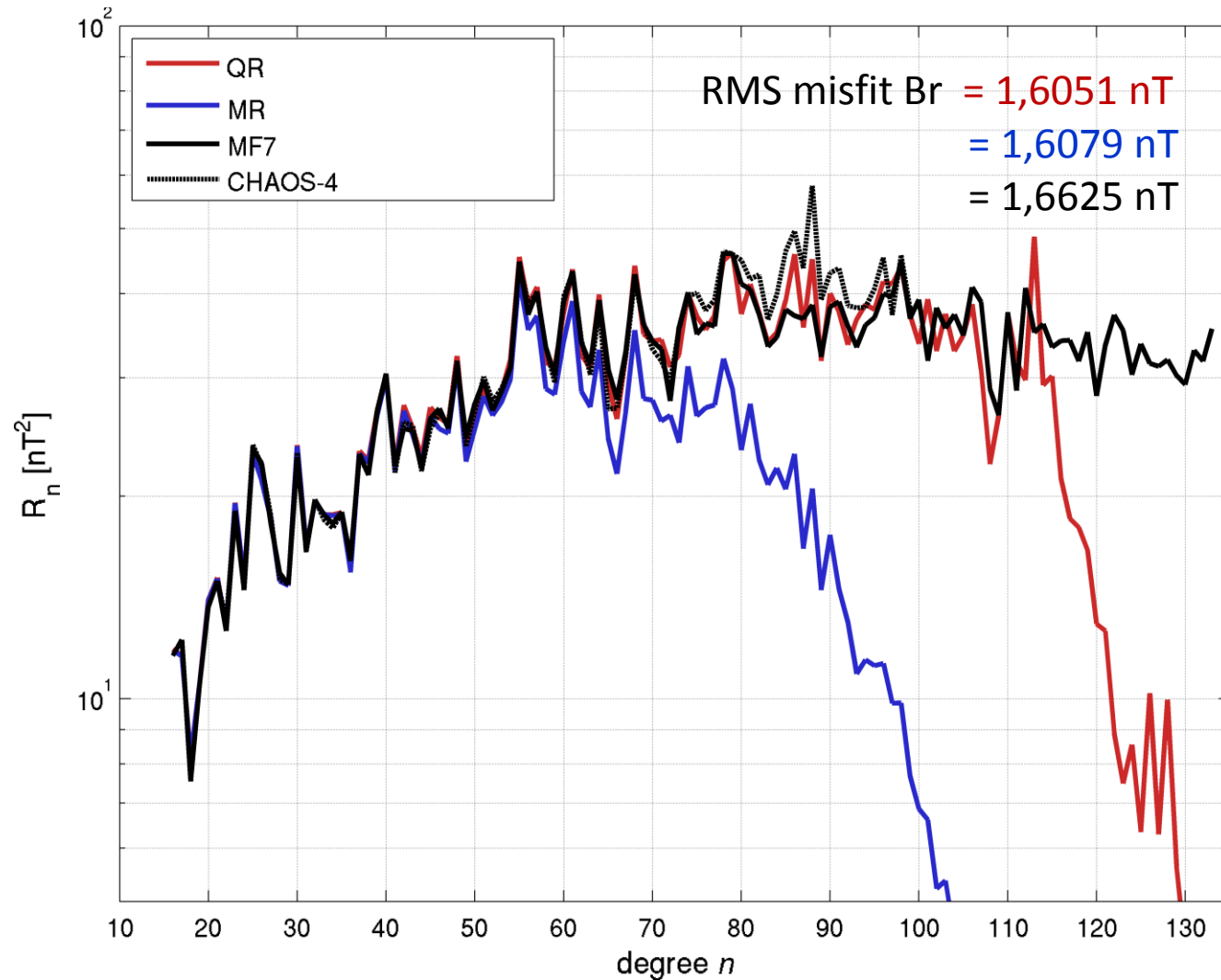
Model Result: CHAMP Data



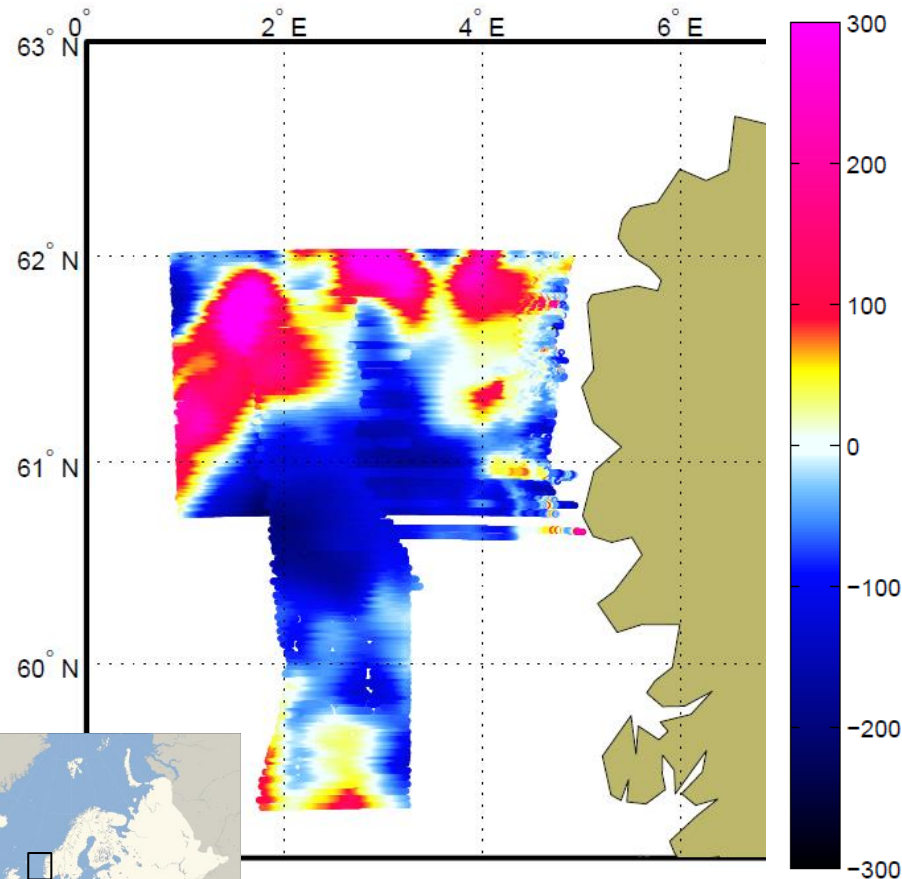
Model Result: CHAMP Data



Model Result: CHAMP Data



Model Result: Airborne Data



Aeromagnetic survey data are kindly provided by NGU

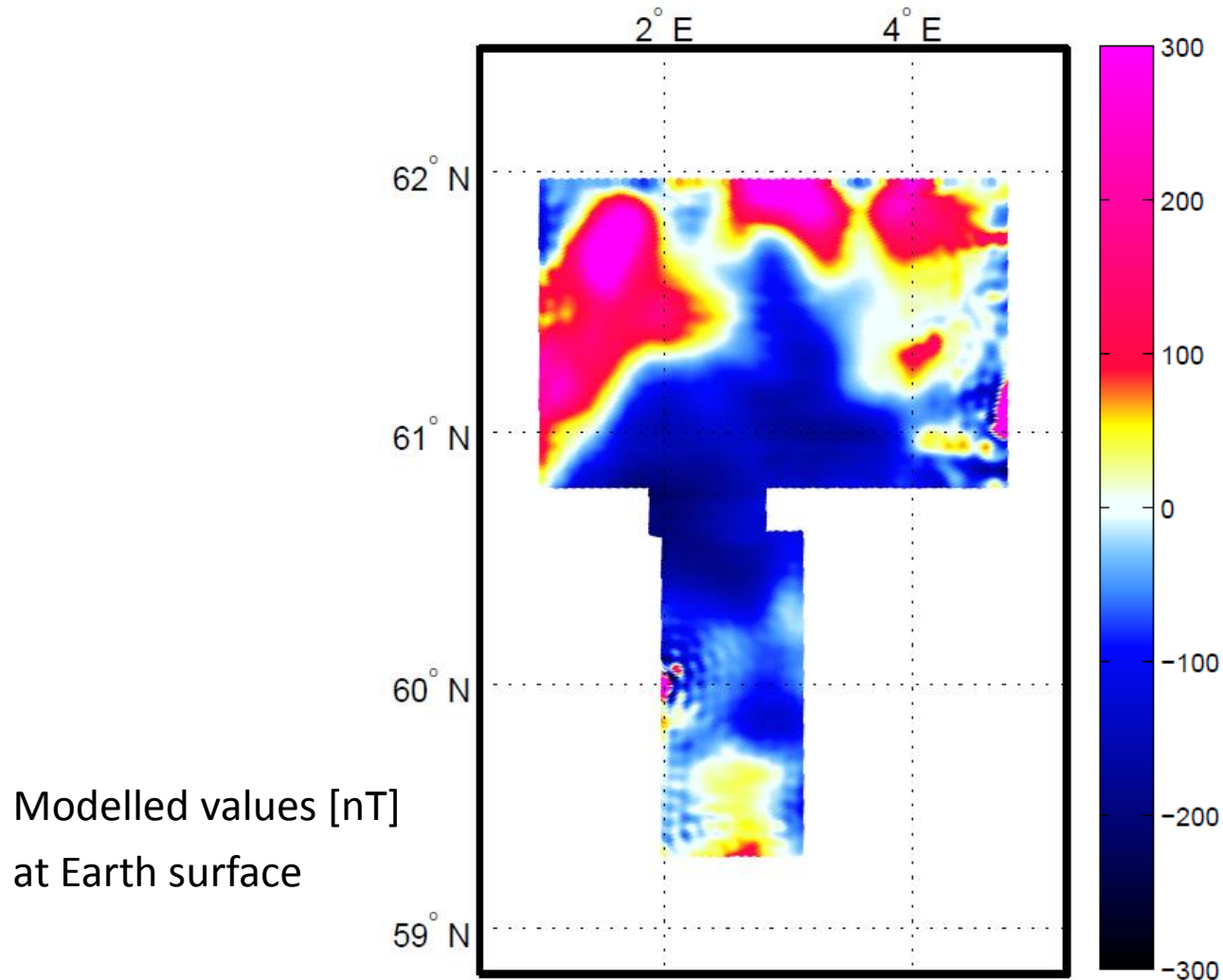
Survey 1 - Viking

Year: 1993
Sensor elevation: 150 m
Line spacing: 0.5 – 2 km

Survey 2 - Fairey

Year: 1971
Sensor elevation: 500 m
Line spacing: 2 – 7,5 km

Model Result: Airborne Data



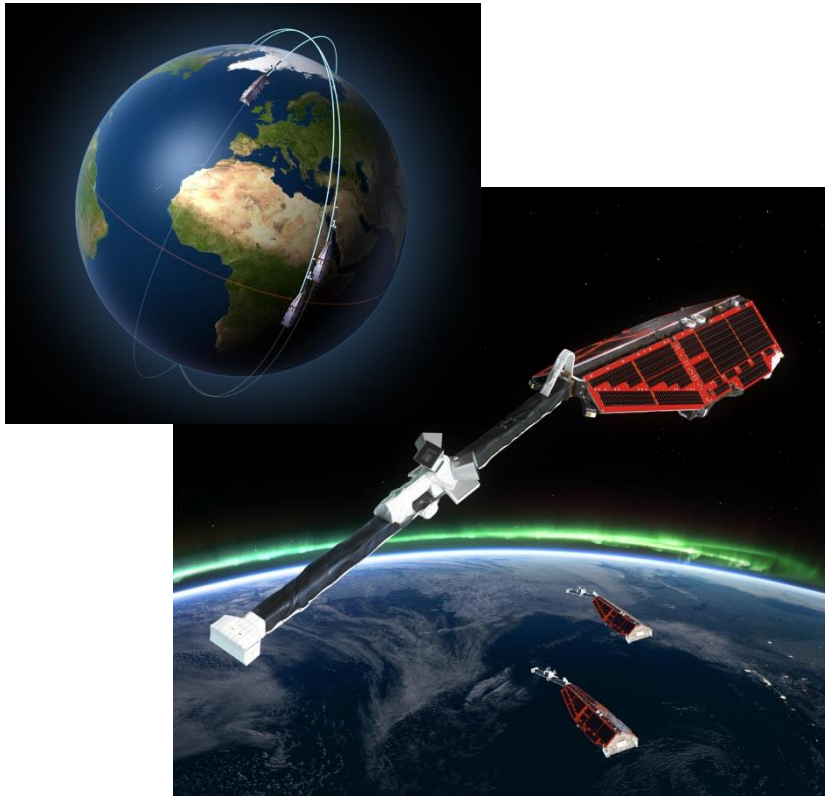
Conclusion

- Lithospheric field modelling based on equivalent potential field source estimation
- Robust, regularized, least squares estimation scheme
- Successful tests using satellite data on a global scale and local airborne data

Advantages of the method:

- Combined local and global applications are possible
- Model regularization can be easily implemented
- Downward / upward continuation
- Method is not sensitive to polar gap problem

Swarm mission



www.esa.int

Launched: 22th Nov 2013

Mission duration: 4yrs

Orbit: 2 satellites orbit side-by-side at an initial altitude of 460 km, decaying naturally to 300 km; the third satellite orbits at about 530 km

Instruments: Vector field magnetometer, absolute scalar magnetometer, electric field instrument, accelerometer, GPS receiver, startrackers and laser retroreflector